Thoracic Aortic Endografting for Trauma

A Current Appraisal

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**Objective:** To explore this newer treatment modality’s benefits, technical concerns, and complications as currently understood during the management of patients with blunt aortic injury (BAI).

**Data Sources:** Data sources included relevant articles from published medical journals and current published texts.

**Study Selection:** Assimilation of the pertinent world’s literature into a select representation of the current status of thoracic aortic endografting for trauma’s (TAET) performance and outcomes.

**Data Extraction:** Comprehensive review of the current literature on BAI.

**Data Synthesis:** Comparison and critical evaluation of the current literature.

**Conclusions:** Endografting is the most frequently used method for repair of BAI. The use of TAET has led to reductions in operative mortality and spinal cord ischemia. Although experience seems promising, a new array of early and late complications must be considered. The positive experience with TAET thus far has provided impetus for endograft engineering and clinical trials specifically for BAI therapy. The ultimate late durability of TAET remains to be defined.

Arch Surg. 2010;145(10):1006-1011

**BLUNT AORTIC INJURY (BAI)** continues to harbor major morbidity and mortality. It remains the second leading cause of death among patients with trauma, secondary only to head injury. Although less than 0.5% of patients with trauma sustain BAI, 75% to 90% die in the prehospital setting. Of those who survive transport, only 50% survive beyond 24 hours without initiation of therapy. Injury occurs most commonly distal to the left subclavian artery (Figure 1).

**DIAGNOSIS AND IMAGING**

Aortography has been the historical method for diagnosing BAI; however, the diagnostic modality of choice has shifted to computed tomography (CT) during the past 10 to 15 years. Debate regarding the sensitivity and specificity of CT was heated during the early part of the past decade. However, newer multidetector, highly resolute systems and volumetric reconstruction have essentially put this argument to rest.

Demetriades et al authored an American Association for the Surgery of Trauma (AASST) Aortic Injury Study Group communication examining changing perspectives in BAI evaluation and treatment between 1997 and 2007. Use of aortography for diagnosis decreased from 87.0% to 83.0% whereas use of CT for diagnosis increased from 34.8% to 93.3%. Today, aortography is essentially used as the initial evaluation portion of the endografting procedure (Figure 3).

In addition to CT and aortography, other methods of BAI diagnosis and imaging include transesophageal echocardiography, intravascular ultrasonography, and magnetic resonance angiography. All these methods...
modalities are specific for identifying BAI in patients with suspected injury. Intravascular ultrasonography and transesophageal echocardiography can also provide helpful real-time information regarding aortic size and seal zone morphologic features during thoracic aortic endografting for trauma (TAET). A classic series of abnormal findings on routine anteroposterior chest radiography have been identified that suggest BAI; however, although routine screening chest radiography has its proponents, it has been reported to miss 7% to 44% of BAI. Given this high rate of missed injury on chest radiography, CT has been widely recommended for all patients who sustain significant blunt trauma.

**TIMING TO SURGICAL INTERVENTION**

The time from diagnosis to surgical intervention has changed significantly in the past 10 years. Since 1960, immediate surgical repair has been advocated. Yet, the widespread use of antihypertensive agents and β-blockers culminating in sheer stress reduction therapy have proved effective in halting subacute progression of BAI. The benefits of delay to definitive treatment until the patient’s physiologic improvement has been recognized. In 1997, mean time from aortic injury to surgical intervention was 16.5 hours, and it increased to almost 55 hours by 2007. Recent multicenter evaluations by the AAST study group regarding time to repair have delineated this benefit more clearly. Regardless of repair method, delay beyond 24 hours after injury emerged as significantly advantageous regarding operative mortality (early vs delayed: odds ratio, 7.8; P = .008). Thus, with the usual physiologic compromise that can occur with severe blunt trauma, these current data and recommendations favor delayed aortic repair in patients suitable for ongoing blood pressure and sheer stress control.

**CLASSIC OPEN SURGICAL INTERVENTION**

Open surgical intervention has remained the mainstay for BAI repair for approximately 50 years. Surgical intervention involves double-lumen endotracheal intubation to facilitate single-lung ventilation of the right lung and aortic clamping via left thoracotomy, providing access to the injured aorta. Once the injured aorta is identified, the operating surgeon must choose between “clamp-and-sew” and alternative perfusion methods. When using clamp-and-sew, the aorta is doubly clamped and an interposition graft is inserted expeditiously. Analysis of this technique has revealed significant mortality of 16% and paraplegia of almost 20%. In fact, the clamp-and-sew technique has been impugned as an independent predictor of paraplegia when open aortic repair is undertaken.

As such, distal perfusion techniques are commonly used during open repair. These techniques encompass a spectrum that includes left-sided heart bypass methods, femoral-femoral bypass, standard cardiopulmonary bypass, and, when necessary, even hypothermic circulatory arrest. Advantages of distal perfusion may include visceral and spinal cord protection. The AAST report suggests a significant reduction in spinal cord ischemic injury using contemporary operative techniques vs historical comparisons (2.9% vs 8.7%, P < .001). This included a substantial increase in the use of bypass modalities over the clamp-and-sew technique. Several systematic meta-analyses have indicated that recent outcomes with open repair include operative mortality of 10% to 20%, paraplegia of 2% to 10%, and stroke of 4% to 6%. However, some researchers have argued that in young patients with trauma, the physiologic burden of open repair is well tolerated and outweighs the risk given the unknown long-term durability of stent grafts.

**THORACIC ENDOGRAFTING FOR TRAUMA**

Endografting for thoracic aortic disease was first reported in 1994. Initial use of endografts was reserved for age-related and aneurysmal disease. A few years later, in 1997, Semba et al reported on the placement of covered stents for the treatment of 10 patients with trau-
matic aortic injuries. Since 1997, endovascular technology has evolved significantly, and TAET is a highly visible treatment method for BAI. In fact, recent evidence shows that it has become the most commonly used method of addressing this formidable injury today.11 Use of endografts is especially appealing in patients with large physiologic burdens from other injuries. Thoracic aortic endografting for trauma does not require single-lung ventilation, thoracotomy, or aortic cross-clamping. In addition, the devices can be deployed without the use of anticoagulation, which is especially advantageous in patients with concomitant head and solid organ trauma. Finally, TAET provides more flexibility for the trauma team and has been implemented in less than ideal environments, including the deployed military setting during Operation Iraqi Freedom.29

Naturally, TAET carries a new set of complications and challenges. Aside from operative mortality and paraplegia, endoleak, access vessel problems, stroke, and inadvertent arch-branch occlusion may occur.11 Currently, endoleak rates are reported to be 4.2% to 14% early and approximately 1% late.23,30 Early endoleak has been suggested to have a role in early death.26 Graft collapse is a severe complication and may potentially lead to aortic rupture and thrombosis and, ultimately, death.30 Additional complications, including stent fracture, migration, and ongoing aortic expansion, have been described.

Individuals who sustain traumatic aortic injury, in general, are younger, with relatively smaller aortas, than those treated for degenerative diseases. Many aortic diameters adjacent to the injury are smaller than 20 mm and taper in the descending component. Thus, the use of available, larger devices designed for degenerative diseases has unmasked serious troubles with graft infolding, graft collapse, aortic thrombosis, and failure when thoracic endografts are significantly oversized.12,31-33 Therefore, it has become evident that oversizing thoracic grafts by only 10% is ideal. Specifically owing to the concern of aortic size in trauma, smaller and tapered endografts have been developed. Dedicated trials for the treatment of traumatic injury using these smaller grafts are under way and allow for TAET in aortas as small as 16 mm. Specifically, trials using smaller TAG (WL Gore & Associates Inc, Flagstaff, Arizona) and TALENT (Medtronic AVE Inc, Santa Rosa, California) thoracic endografts have been designed and are enrolling participants.

Arterial access via the iliofemoral system may also present challenges, particularly compared with the older population undergoing endografting for aneurysm and dissection. In TAET, the femoral and iliac vessels usually do not have significant calcification or thrombus burden. Instead, they are smaller and narrowing, with a higher risk of iatrogenic injury, such as perforation, tearing, thromboembolism, and rupture. Commercially available thoracic endografts are mounted on delivery systems with 20- to 26-French inner diameters (7.6- to 9.1-mm outer diameter). Thus, realistically, a continuous iliac system at least 8 mm in diameter throughout is necessary.

When iliofemoral access is not appropriate, graft conduits can be placed along the iliac arterial system, usually the common iliac, or the terminal aorta.33,34 These placements are accomplished via relatively small retroperito- neal incisions. The graft can be amputated after the procedure, and the stump can be oversewn in a straightforward

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Figure 3. Aortic angiogram of blunt aortic injury (BAI). A, Standard left anterior oblique arch aortogram showing BAI at the aortic isthmus. B, Completion aortogram after thoracic aortic endografting for trauma (TAET) to repair this BAI. Currently, most use of aortography is for landmark and injury definition before TAET.
manner. In patients in whom the iliofemoral system is adequate, reasonable results have been achieved by performing TAET via a totally percutaneous approach.  

Brachial access can help with TAET when arch angulation seems problematic. Arteriography via the brachial artery can help delineate proximal seal zones and decrease contrast load. In addition, a stiff wire snared between brachial and groin access sites can help decrease arch angulation and increase graft pushability and device tracking. The need for brachial access has been less common in trauma because significant angulation usually is associated with degenerative disease in older patients. When proximal seal zones were not adequate, subclavian coverage has been used. If the subclavian is covered, patients must be monitored for vertebrobasilar insufficiency and problematic upper extremity ischemia. European Collaborators on Stent/Graft Techniques for Aortic Aneurysm Repair registry data, largely based on thoracic endografting for degenerative diseases, have revealed that intentional coverage of the subclavian artery without revascularization is a significant predictor of spinal cord ischemia, and this has been substantiated by a meta-analysis. Whether this may also be a distinct dilemma in patients with trauma undergoing TAET remains to be clarified.

WHAT ARE THE DATA?

Studies aimed at comparing open surgical repair and TAET were initially single-institution trials, and these have continued to mature. In a representative study, Rousseau et al compared 29 patients undergoing TAET with a cohort of 35 patients repaired via the open technique in 2005. They found open repair mortality of 21%, with paraplegia of 7%. The TAET group experienced no mortality or paraplegia. This skilled group recently described their ongoing experience with endografting for trauma. Although there continued to be no perioperative deaths, 1 temporary paraparesis was noted. At mean follow-up of almost 3 years, no aortic reinterventions were required in individuals undergoing TAET.

The largest singular cohort comes from the multi-center BAI data stemming from the AAST aortic injury study group reports. The initial report from this group, in 1997, provided important information regarding open repair (AAST1). As mentioned previously herein, the most recent communications have provided more pertinent information on BAI therapy. A total of 193 patients (68 open repair and 125 TAET) were enrolled in AAST2 between 2005 and 2007. During this time, 64.8% of BAI was repaired via TAET. Not only has the newer AAST2 study contrasted contemporary open vs endovascular repair experiences in a multicenter manner, but it illustrated the changing perspectives developing since 1997. Operative mortality has remained constant at 16% in open repair and is significantly lower with TAET (9%, P = .001). After adjusting for systemic injury degree and extrathoracic injury, mortality and pulmonary complications remained significantly lower with TAET. Nevertheless, repair site complications, usually from device delivery access, have been recognized to be more prevalent in TAET.

Broader understanding of the place of TAET in aortic injury therapy has been further exemplified by recent meta-analyses. Tang et al evaluated 33 communications between 2001 and 2006. Three hundred twenty-nine patients were found who underwent open repair and 370 who underwent TAET. There were no differences

Figure 4. Treatment algorithm for thoracic injury. ASC indicates ascending aorta; BAI, blunt aortic injury; CRX, chest radiograph; CT, computed tomography; PSA, pseudoaneurysm; SCA, subclavian artery; and TAET, thoracic aortic endografting for trauma.
in age, injury severity score, or technical success between the 2 strategies. Follow-up averaged 4 years in those with open repair but only approximately 2 years in those having TAET. Nevertheless, perioperative mortality (7.6% vs 15.2%), spinal cord ischemia (0% vs 5.6%), and stroke (0.85% vs 5.3%) were all statistically less frequent in the endografting group. Comparable findings have been reported by Xenos et al combining 17 studies from 2003 to 2007. In yet another systematic review by Hoffer et al, similar reductions in mortality and paraplegia were identified comparing TAET with open repair. They also compiled 667 reported TAET procedures regardless of open comparison. In this group, they identified early endoleak in 4.2% and late endoleak in 0.9%. Migration was negligible. Although seemingly adequate, almost 1 in 10 early deaths were attributed to endoleak and, essentially, treatment failure. In these systematic meta-analyses, the technical success of TAET was estimated to be greater than 96%, thus establishing its applicability as a reasonable treatment option.

Without prospective data to lead us, these collective evaluations are perhaps the most compelling discussion in favor of TAET currently. The developing body of literature is captivating, and a paradigm shift toward endovascular repair continues. Proponents point out that in light of these data, TAET seems to provide superior immediate results, and, at best, it is definitive treatment. At worst, it may provide a bridge to a later, elective procedure when the patient is physiologically optimized, or even recovered, from concomitant injuries.

**DOES EVERYONE NEED REPAIR?**

Prolonged medical therapy using sheer stress reduction without ultimate repair is debated but not currently commonplace. In 2001, the University of Tennesse at Memphis retrospectively evaluated data for patients with BAI between 1994 and 2000. A new definition of minimal aortic injury was used to describe injury with less than 1 cm of intimal flap and no periadventitial hematoma. Nine patients were identified, and 6 of the 9 were observed. Of those, 3 developed pseudoaneurysm; however, none of the observed patients died as a result of aortic injury. Other studies exist regarding observation for minimal aortic injury. Fisher et al observed 3 patients with no deaths and reported 10 other such cases in the literature. With improvements in imaging technology, particularly CT, and its increased use, these minimal injuries are now frequently diagnosed. With quick and effective blood pressure control, the need for surgical repair is unclear. In a subset of patients, some have advocated for selective repair. No definitive conclusions can be made regarding the need for repair in those with minimal aortic injury currently, but it is likely that this debate will intensify as technology and medical therapy continue to improve. Based on current data, in centers where imminent endovascular capability for TAET is available, Figure 4 suggests an algorithm for the management of BAI.

In summary, TAET has undergone significant changes since its introduction more than 10 years ago. Commercially made devices have improved, and ongoing modifications to enhance TAET are occurring. Endografting is now the most common method for repair of aortic injury and is becoming more commonplace. Although experience seems promising, this new technology provides a new array of early and late complications that must be considered, and the ultimate late durability of TAET remains to be defined. However, given the significant multisystem trauma sustained by most patients with BAI in conjunction with the newer evidence indicating reductions in mortality and spinal cord ischemia compared with open repair, TAET provides surgeons with an excellent additional option for addressing this difficult injury.

**Accepted for Publication:** November 13, 2009.

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**Author Contributions:** Study concept and design: Propper and Clouse. Acquisition of data: Propper and Clouse. Analysis and interpretation of data: Propper and Clouse. Drafting of the manuscript: Propper and Clouse. Critical revision of the manuscript for important intellectual content: Propper and Clouse. Obtained funding: Clouse. Administrative, technical, and material support: Propper and Clouse. Study supervision: Propper and Clouse.

**Financial Disclosure:** None reported.

**REFERENCES**


The incidence of blunt vehicular trauma is on the rise worldwide, especially in emerging health care sectors. Although BAI occurs in less than 1% of motor vehicle crashes, it accounts for 16% of accident-related deaths, second only to head injuries. As highlighted by Propper and Clouse, much progress has occurred in the past 2 decades in the detection and management of BAI. Buoyed by the development of stent-graft technologies in general, and endografting for aortic aneurysmal disease in particular, endovascular repair has become the most common and, in fact, preferred treatment for BAI. Although randomized controlled trial data are unavailable, a prospective multicenter study (AAST) and at least 3 meta-analyses of controlled trial data are unavailable, a prospective multicenter study (AAST) and at least 3 meta-analyses...